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Investigations on Zooplankton in Norwegian Waters and in the Norwegian Sea during 1957—58

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INTRODUCTION

As in earlier years, zooplankton was sampled regularly during 1957 and 1958 at fixed oceanographical stations along the coast of Norway and Spitsbergen, at st. "M" in the Norwegian Sea, and during cruises in Norwegian coastal waters and in the Norwegian Sea. The observations from earlier years have been published and the technique of sampling and handling of the plankton material described (WIBORG 1954, 1955, 1958).

THE ZOOPLANKTON AT THE FIXED OCEANOGRAPHICAL STATIONS

Sognesjøen. (61°04′ N, 04°50′ E). In 1957 there were peaks in plankton volume in April and June (Fig. 1). No samples were taken between the middle of June and the end of September. The monthly figures were about average (WIBORG 1958).

In 1958 plankton was sampled during March, April, September, October and December. The figures were very low, with a maximum of 2.5 ml per haul in April. — A single *Salpa fusiformis* was taken in the middle of September.

Skrova. (68°07.5′ N, 14° 39.4′E). In 1957 the spring maximum in the upper 50 m occurred in June, a secondary maximum in October (Fig. 2). In the hauls from bottom to surface a peak in plankton volume occurred in February and March, the main maximum in August.

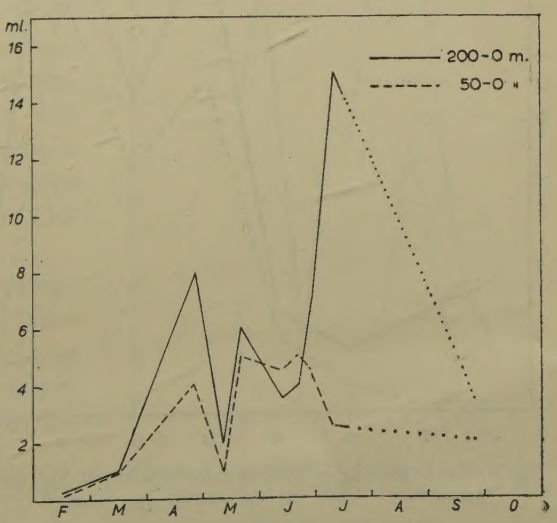

Fig. 1. Variations in volume of zooplankton at Sognesjøen in 1957. Nansen net hauls.

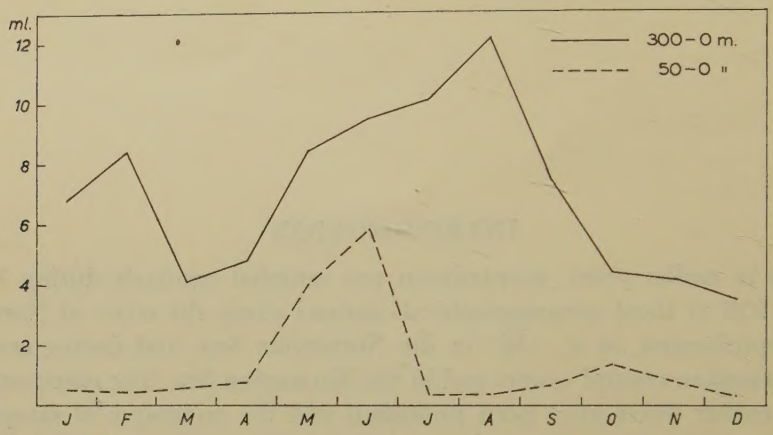

Fig. 2. Variations in volume of zooplankton at Skrova in 1957. Monthly means, Nansen net hauls.

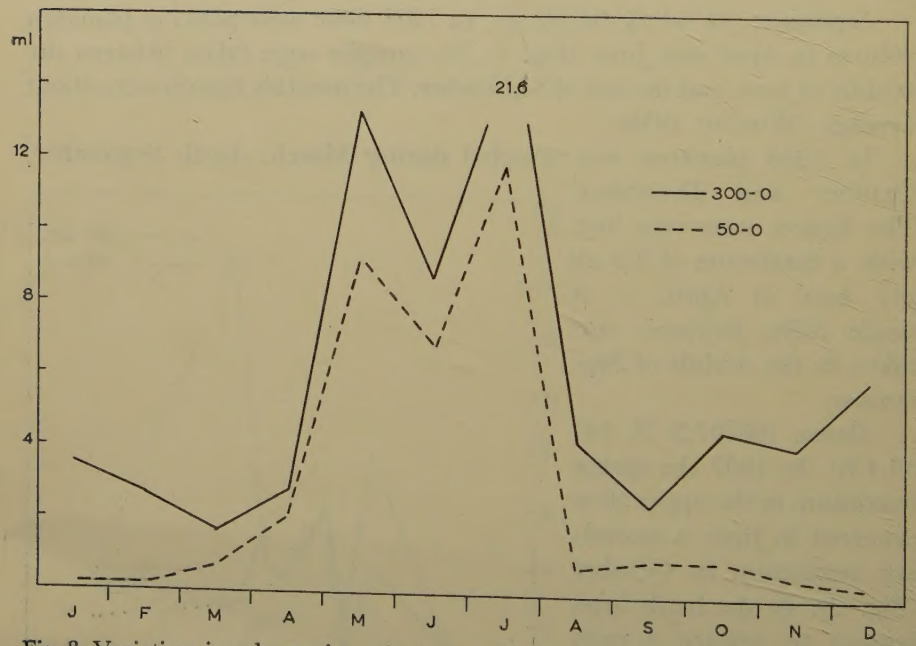

Fig. 3. Variations in volume of zooplankton at Skrova in 1958. Monthly means, Nansen net hauls.

In 1958, as in the year before, the winter minimum was observed in March, maxima for all water layers in May and July (Fig. 3). The plankton was more rich than in the previous year, especially in July. The increase from September to December is possibly due to an accumulation of plankton from adjacent areas in the deeper layers.

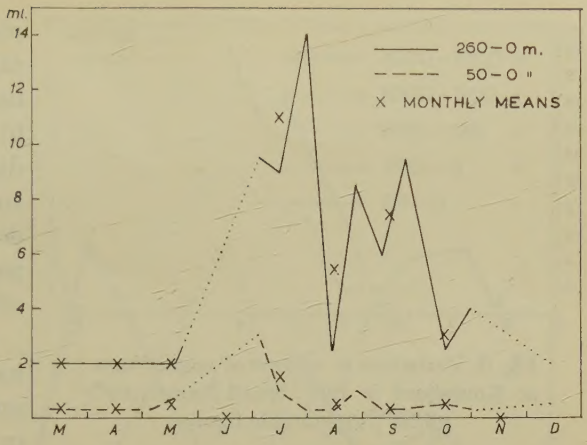

Fig. 4. Variations in volume of zooplankton at Skarsvåg in 1957. Nansen net hauls.

As in 1955, large numbers of *Salpa fusiformis* were taken throughout October. They are not included in the plankton volumes.

Skarsvåg. (71°10.5' N, 25°55.6' E). In 1957 the plankton was scanty from March to May (Fig. 4). No plankton hauls were taken from the middle of May to the end of June. During the second half of the year the plankton was most abundant in the upper 50 m at the beginning of July, and in the total water column peaks occurred in July, August and September, somewhat delayed in relation to the previous year. On the whole, the plankton was less abundant than in 1956, but salps were numerous throughout October.

In 1958 plankton was sampled from the end of June to November (Fig. 5). Peaks in volume occurred in July and September, and the plankton was more rich than in 1957.

At *Kongsfjord*, western Spitsbergen, (79°00' N, 11° 30'E), the

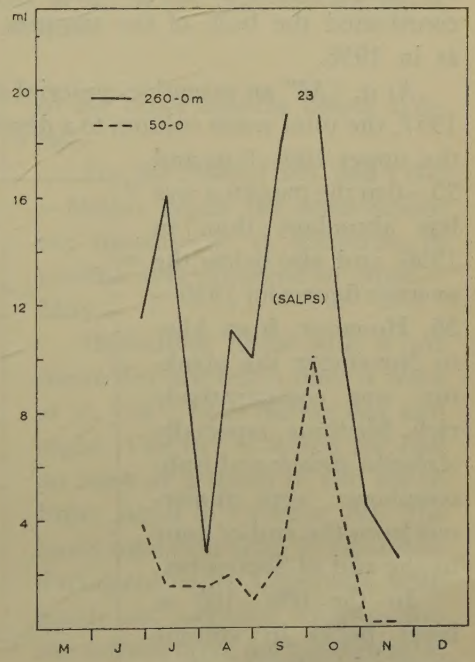

Fig. 5. Variations in volume of zooplankton at Skarsvåg in June—November 1958. Nansen net hauls.

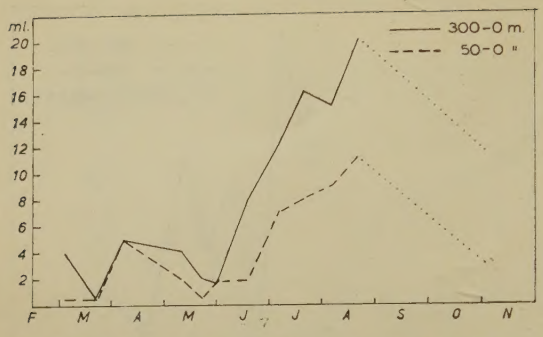

Fig. 6. Variations in volume of zooplankton at Kongsfjord in 1957. Small Nansen net, "8/50", and double figures.

plankton hauls in 1957 were taken from March to August, and in November (Fig. 6). A Nansen net, 50 m in diameter, was used, and all volume figures have been doubled in order to be comparable with those of the other stations.

In 1957 the volume curve had a small peak in April, and rose from a minimum in May to a maximum in August. In November the figures were still relatively high.

In 1958 (Fig. 7) the plankton was more abundant, with two peaks in volume, a smaller one in June, and the main peak in August. There was also some increase during the last half of September. In the upper 50 m the plankton was most abundant from June to August, and at the end of September, or later. — In both years *Calanus finmarchicus* constituted the bulk of the samples, but the plankton was not so rich as in 1956.

At *st. "M"* an extensive material of zooplankton was collected during 1957, the total water column to a depth of 2 000 m being fished (Fig. 8). In the upper 100—0 m and 25—0 m the plankton was less abundant than in 1956, and also below the average figures for 1950—56. However, from May to November the plankton was comparatively rich. Medusae, especially *Aglantha digitale* and siphonophores, were numerous from the end of June to the end of September.

In the 600—100 m layer peaks in volume occurred in April—May, August and October. The figures for April, May and August were about average (1950–56), those

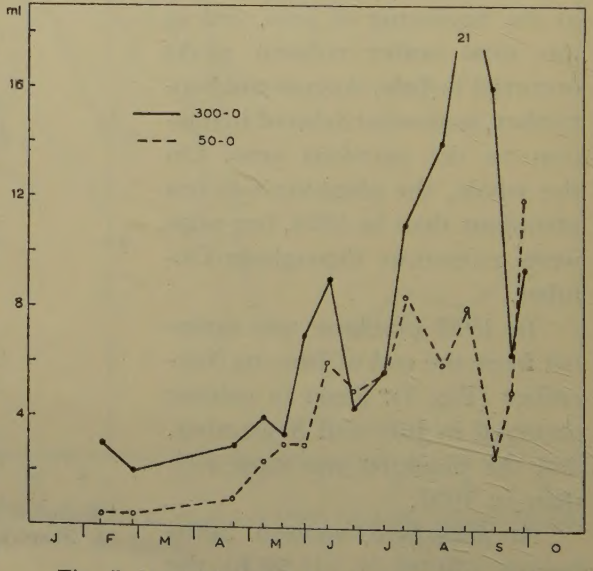

Fig. 7. Variations in volume of zooplankton at Kongsfjord in February—October 1958. Small Nansen net, "8/50", and double figures.

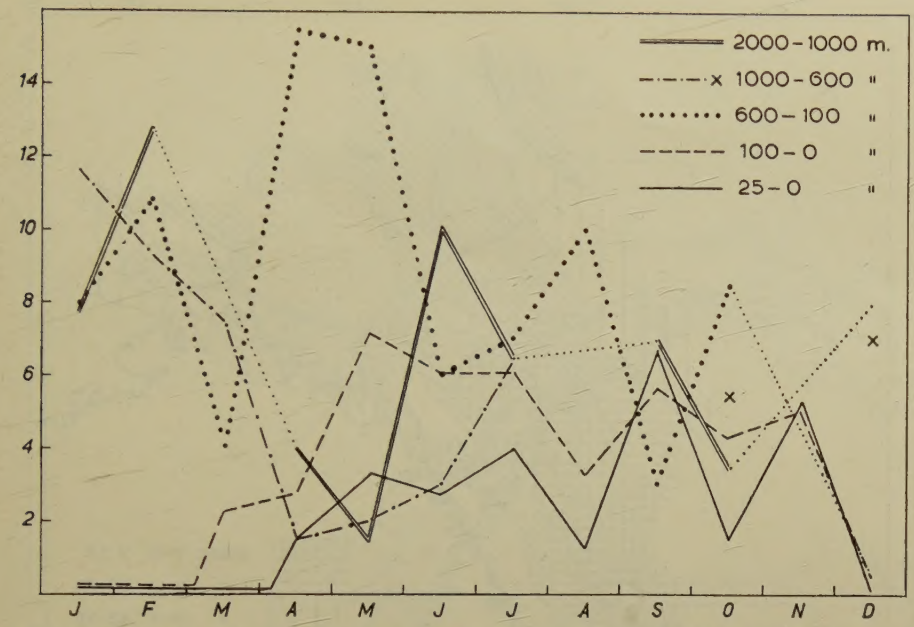

Fig. 8. Variations in volume of zooplankton at st. "M" in 1957. Monthly means, Nansen net hauls.

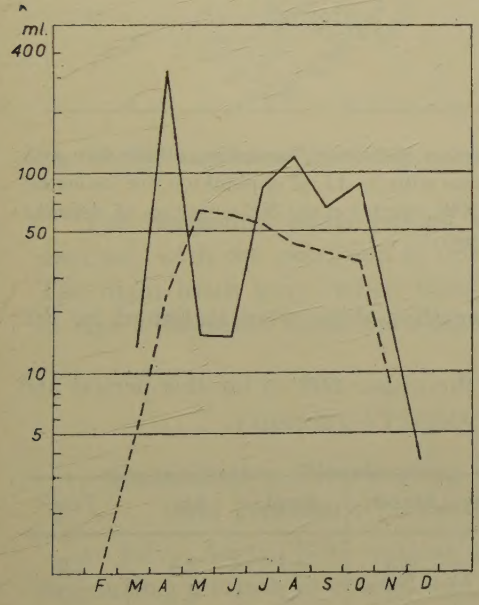

Fig. 9. Variations in volume of zooplankton at day (broken line) and night (continuous line) in horizontal surface hauls with a one metre egg net at st. "M" in 1957, adjusted to 1 hour's haul. Monthly mean figures and logarithmic scale.

of the other months below average.

For the 2 000–1 000, and 1 000 —600 m layers the observations are incomplete. A minimum in volume was observed in April—May.

Horizontal hauls with a one metre net are taken once a week at st. "M", both during day and night. The net is towed for half an hour at a speed of two knots. From April to October 1957 the hauls were rich (Fig. 9) especially during the night. Copepods, krill, partly also medusae, migrate into the surface layer during the night, especially during spring and autumn.

In 1958 plankton was sampled at st. "M" from January to the end of June. (During the latter

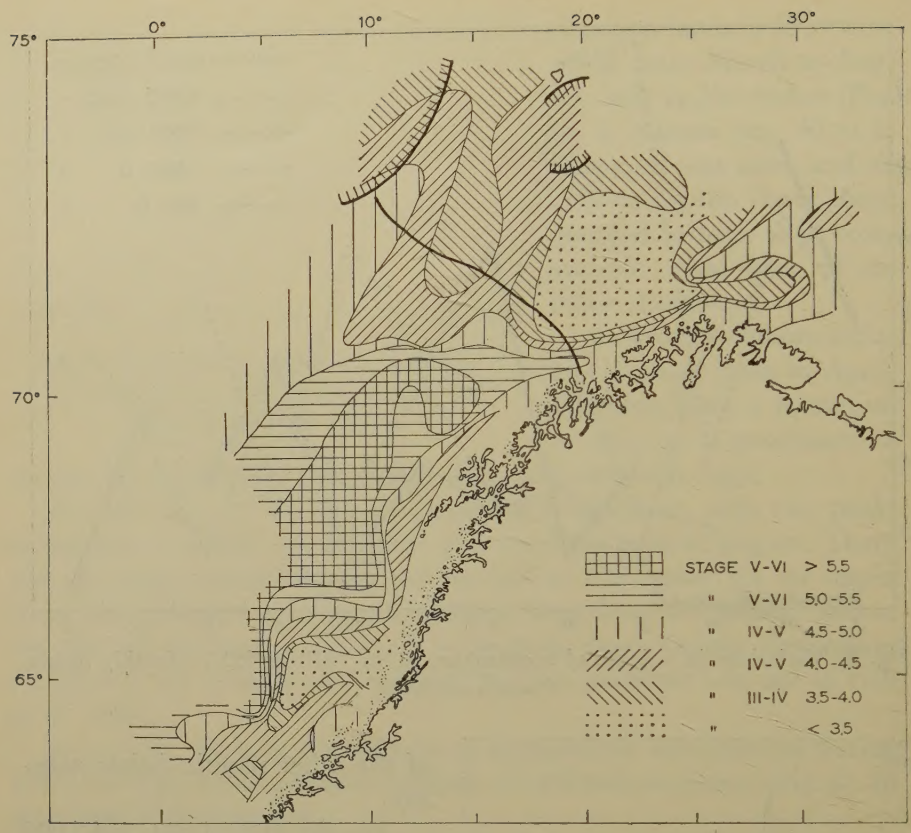

Fig. 10. The horizontal mean stage distribution of *Calanus finmarchicus* off western and northern Norway in July—August 1957. Areas with 5—11 ml of plankton are indicated by combed lines. Thick line, running SE—NW: border of the NE extention of *Aglantha digitale*.

half of the year the Norwegian weather ships were stationed in the Denmark Strait at st. "A").

The monthly mean volumes in the upper 600 m for this period are shown in the table below (in ml):

Haul	January	February	March	April	May	June
25— 0 m	0.5	0.5	0.5	0.7	2.4	2.0
100— 0 m	0.5	0.5	1.3	1.7	4.1	2.7
600—100 m	3.5	0.5	5.5	—	4.0	7.0

As in previous years, a maximum occurred in the upper 100 m in May, but the plankton was less abundant than in 1957.

Fig. 11. The isoterms in 20 m and isohalines (in part) at 0 m, July—August 1957.

The horizontal hauls yielded small quantities of plankton during daytime, with the exception of one haul of 160 ml at the end of May. The night hauls were richer, with a maximum mean figure of 127 ml in April. No night hauls were taken in January and March.

OBSERVATIONS FROM CRUISES

Quantitative Distribution of Zooplankton off Western and Northern Norway in July—August 1957

In July—August 1957 vertical hauls were taken with a Nansen "8/70", net during a cruise in coastal and offshore waters of northern Norway (see Wiborg 1960c).

The plankton was in general scanty. Southwest of a line running northwestwards from Fugløy (Fig. 10), *Aglantha digitale* dominated, except near the coast, where *Calanus finmarchicus* constituted the main

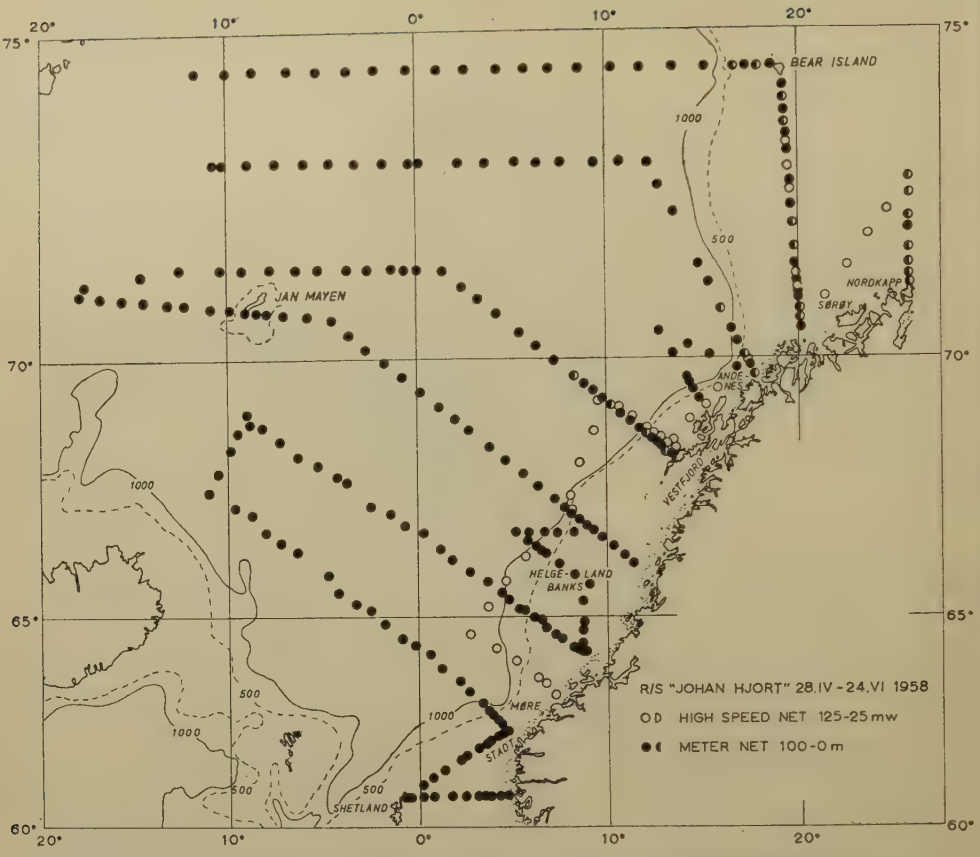

Fig. 12. Plankton stations in the Norwegian Sea April—June 1958.

volume of the samples. North and northeast of the border mentioned, the same copepod was also most common, but only south and west of Bear Island the plankton reached 5—11 ml per haul.

Horizontal Stage Distribution of Calanus finmarchicus in July—August 1957

The stage distribution of *Calanus finmarchicus* was investigated, and the average stage distribution plotted (Fig. 10). As the time interval between the northern and southern stations is more than a month, the chart does not indicate the synoptic stage distribution.

One of the most conspicuous features is the core of stage V—VI running northeastwards from the coast, ending at the northern limit of the distribution of *Aglantha digitale*. Close to the coast stage III and lower stages dominate in two areas, on the southern Helgoland banks and northwest of Sørøy.

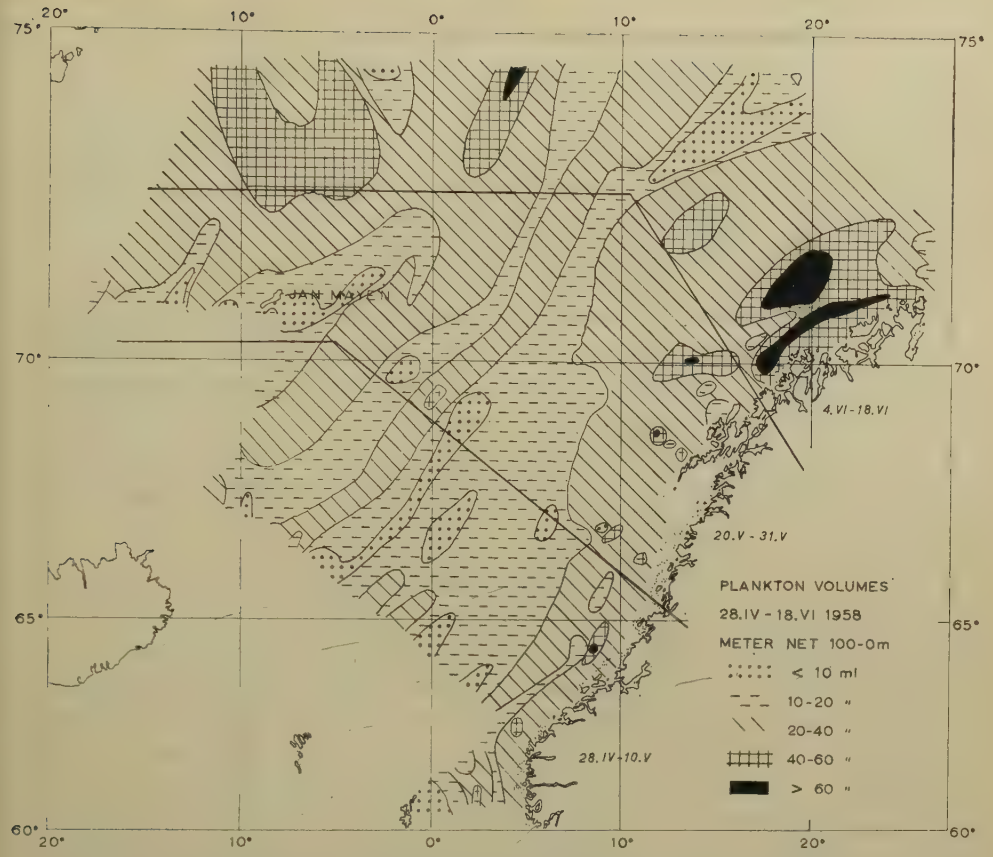

Fig. 13. The quantitative distribution of zooplankton, April—June 1958, one metre egg net, 100—0 m.

In the Møre area there is a second spawning of *Calanus finmarchicus* in May—June. The copepodites of stage IV—V off Møre, as well as stage III at Helgoland may be referred to this spawning, while the core of stage V—VI further seawards probably is the off-spring from the spring spawning. According to Pavstikhs (1956) the biological spring in this area occurs in June, later than in the coastal areas. Farther westwards, and south and west of the Bear Island, the development is still more retarded.

The chart of the stage development bears a clear relation to the hydrographical conditions. Fig. 11 has been reproduced by the courtecy of Mr. R. Ljøen. The agreement between the two charts is very striking, e. g. in the area between Bear Island and Norway. A paper on the hydrographical conditions in these waters is in preparation (Ljøen, in press).

Quantitative Distribution of Zooplankton in the Norwegian Sea in April—June 1958

During a cruise with R/S "Johan Hjort" in the Norwegian Sea in May—June 1958 an extensive zooplankton material was collected (Fig. 12). The plankton, being taken in vertical hauls with a one metre net (mesh size ·5 mm) was mainly intended for a study of the distribution of fish eggs and larvae (Wiborg 1960b), and is therefore of restricted value for a general study of the plankton.

The quantitative distribution of zooplankton is shown in Fig. 13. In the northwestern Norwegian Sea the plankton was fairly abundant, mainly consisting of *Calanus hyperboreus*. The central area was poorer, but the Norwegian coastal and bank areas were again richer in plankton. *Calanus finmarchicus* was dominating, but in some regions, especially in the northeastern area, fish fry, krill (euphausiids) and medusae played an important part.

Echo Recordings of "Plankton"

When echo sounders are operated in coastal or oceanic areas, a shallow scattering layer, giving diffuse echoes, may be recorded continuously for hundreds of miles, especially during the spring-autumn period. The recordings vary considerably both with respect to intensity and depth, but are usually limited to the upper 30–50 metres. Such a scattering layer has sometimes been identified as echoes from small fish, but in general the opinions as to the identity of the layer are somewhat divergent. In a freshwater lake, Cushing & Richardson (1955) were able to associate diffuse echo traces with the abundance at a certain depth of copepods and cladocerans, while similar traces in the North Sea were identified as echoes from krill. Fraser (1957) stated that *Calanus finmarchicus* and salps were ineffective as sound reflectors for the echo sounders used on board the Scottish research ship "Scotia".

During the whole cruise in May—June 1958 a special SIMRAD echo sounder, producing signals at 27 kc., was run continuously. For each half hour period the operators noted the average vertical extent of the recording (e. g. 10—50 m, 5—25 m), and made estimates of the intensity on a subjective scale from 1 to 6. By combining these two factors, a chart was prepared (Fig. 14). If we compare this chart with the quantitative distribution of plankton (Fig. 13), a considerable disagreement is found in many areas, particularly in the northwestern area, where the plankton was abundant, but the echo sounder failed to give any recordings. The border of zero recording approximately follows the 3°—4°C isoterms at the 20 m level. (Fig. 16). In the central area the echo recordings are of low intensity, and the plankton is also com-

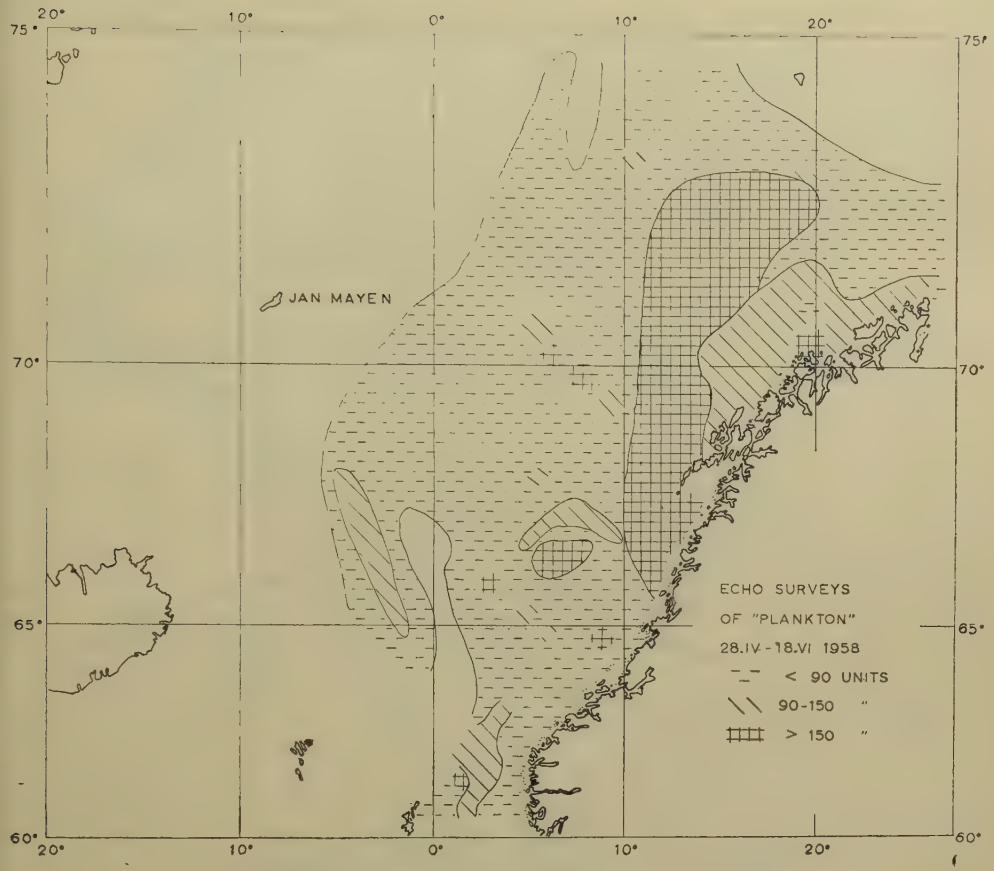

Fig. 14. Echo recordings of "plankton", April—June 1958.

paratively scarce, but in the eastern part the area of maximum recording does not coincide with the maximum abundance of plankton.

In order to find out which organisms might possibly be responsible of the echo recordings, all the species present in the plankton samples were listed. Five groups were selected as potential sound reflectors because of their size, namely appendicularians, chaetognaths, krill, fish fry and medusae. The chaetognaths occurred on nearly all the stations and were accordingly of no use for indicating any correlation with the echo soundings. In the remaining groups the following relations were found:

In the areas without any recording:

No. of stations without recording	No. of stations with catches of:				
	Appendicularians	Krill	Fish fry	Medusae	Nil
68	4	25[1]	2[1]	0	40

[1] Single specimens only.

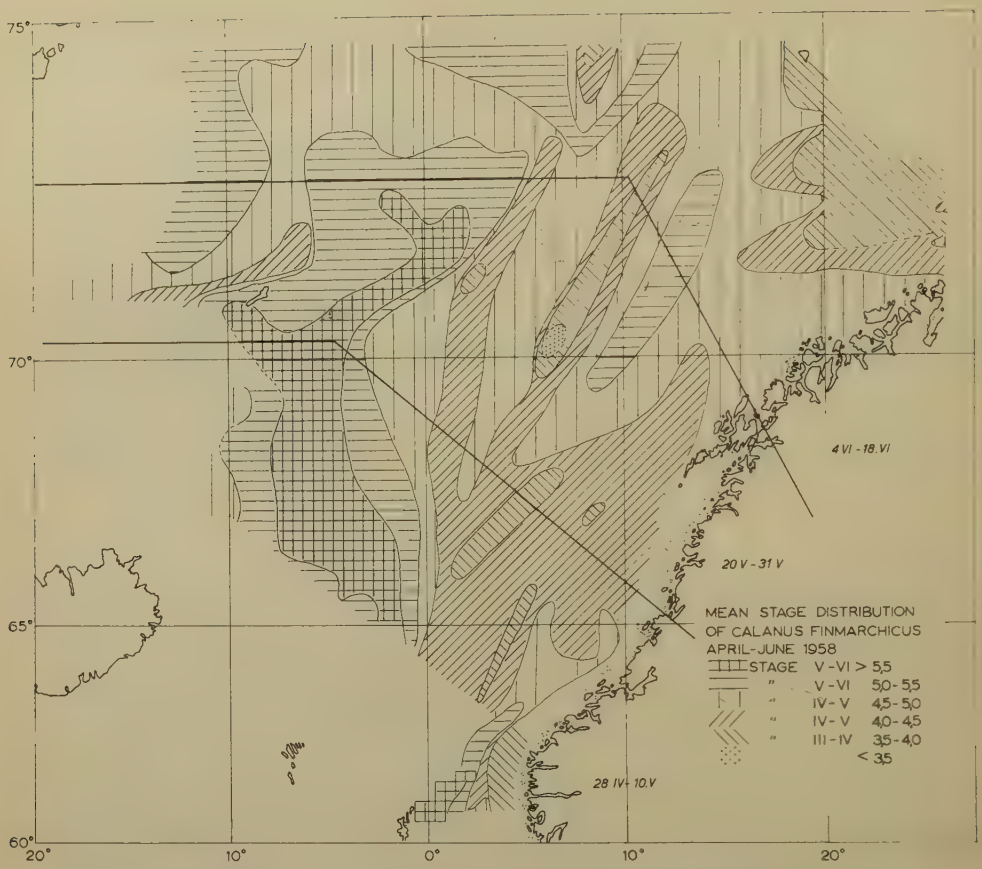

Fig. 15. The horizontal mean stage distribution of *Calanus finmarchicus* in April—June 1958.

In the areas with recording of "plankton":

No. of stations with recording	No. of stations with catches of:				
	Appendicularians	Krill	Fish fry	Medusae	Nil
157	65	111	85	41	5

Krill, fish fry and medusae did not occur in the "negative" area, except as single specimens. In the "positive" area only 20 of the stations yielded merely appendicularians and/or medusae. At the remaining stations krill and fish fry were also present.

In the areas with maximum of echo recordings, krill and fish fry were taken at all stations, partly in large numbers.

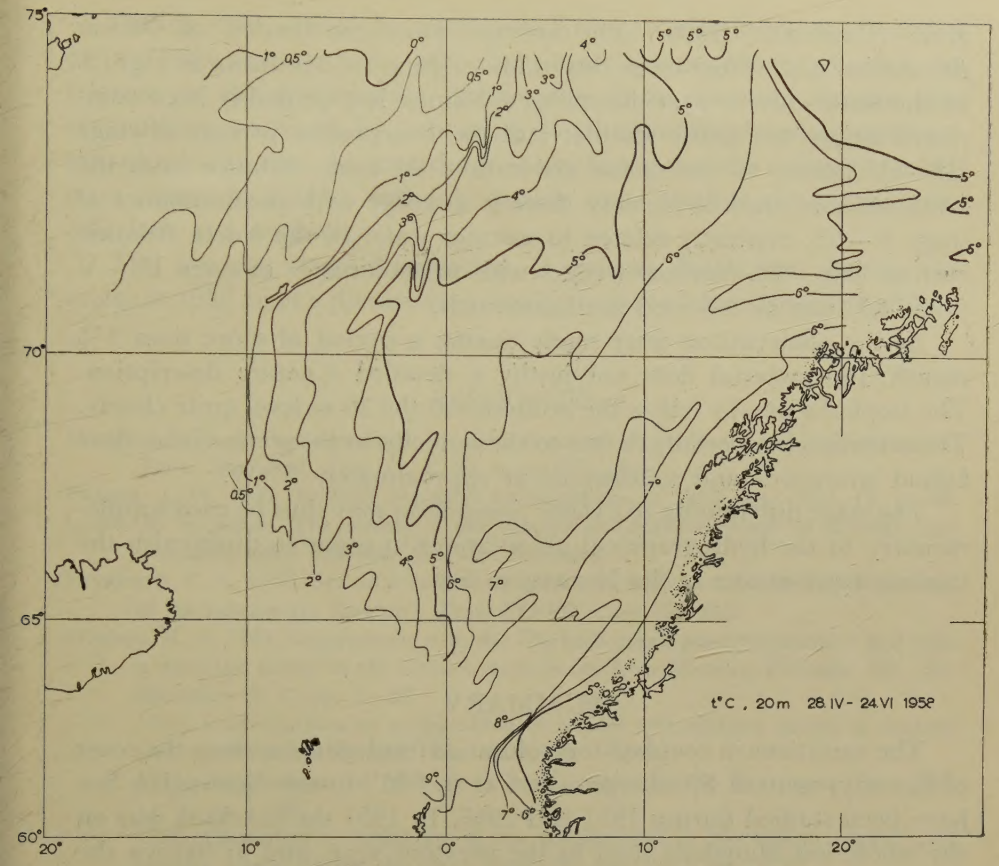

Fig. 16. The isotherms in 20 m, April—June 1958.

It seems as if krill and fish fry are responsible for the major part of the diffuse shallow scattering. In a few cases small squid have been caught, and they may probably play a certain part as sound scatterers. The observers are, however, of the opinion that the echoes caused by squid may be distinguished from other echo signals.

Horizontal Stage Distribution of Calanus finmarchicus in April—June 1958

In a plankton net with mesh size · 5 mm, nauplii and stage I copepodites of *Calanus finmarchicus* are not caught quantitatively (Wiborg 1948). It may although be of some interest to compare the stage distribution in the various areas. The biological spring starts in March—April along the western and northwestern coasts of Norway, in May—June in the central Norwegian Sea, and in July—August in the northwestern

areas (PAVSTIKHS (1956). The average stage distribution of *Calanus finmarchicus* in the Norwegian Sea in May—June 1958 is shown in Fig. 15. In the south-eastern part the spring spawning had probably been completed before the cruise started, and the copepodites present of stage III—IV belong to the spring generation. At some distance from the south-western coast of Norway there is a wedge with predominance of stage V—VI, evidently related to warmer water of the North Atlantic current (Fig. 16). Various wedges with predominance of stage IV—V (4.0—4.5) can be followed northeastwards.

As the observations were made during a period of more than 1½ month, the material does not justify a detailed synoptic description. The isopleths usually follow the isotherms at the 20 m level quite closely. The attention is especially drawn to the isopleths in the section from Bear Island westwards and southwards at approximately 5° W.

The stage distribution of *Calanus finmarchicus* may thus be used supplementary to the hydrographical observations in order to distinguish the various water masses in the Norwegian Sea.

SUMMARY

The variations in zooplankton volume at fixed stations along the coast of Norway, western Spitsbergen, and at st. "M" in the Norwegian Sea have been studied during 1957 and 1958. In 1957 the plankton was on the whole less abundant than in the previous year, and at Skrova the spring maximum also occurred one month later than in 1956.

In 1958, the plankton volumes were again larger, except at st. "M". Peaks in volume were observed at Skrova in May and August, at Skarsvåg near North Cape, and Kongsfjord, western Spitsbergen, in July and September.

Salps were abundant at Skrova and Skarsvåg in October 1958.

Vertical hauls were taken with a Nansen net in coastal and offshore areas of northern Norway in July—August 1957. The plankton was as a rule very scarce, except in an area west and south of Bear Island, where about 11 ml per haul were taken, mainly *Calanus finmarchicus*. In the offshore areas farther south, *Aglantha digitale* dominated.

A chart of the average stage distribution of *C. finmarchicus* revealed a picture very similar to that represented by the isotherms at 20 m level.

Zooplankton was sampled in vertical hauls with a one metre net in the Norwegian Sea and adjacent areas in May—June 1958. The plankton was most abundant in the cold, northwestern parts of the sea, and off the coast of northern Norway.

During most part of the cruise a shallow scattering layer was recorded on an echo sounder. The recordings were quantitatively charted. In relation to the quantitative distribution of zooplankton various discrepancies were found. By comparing the distribution of various plankton organisms with the echo recordings, it was found that the echoes probably were caused by fish fry and euphausiids, some possibly also by appendicularians and medusae.

The average stage distribution of *Calanus finmarchicus* during the cruise in 1958 gives a picture very similar to that of the isotherms at 20 m.

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